Editors Note — This article has been created to provide one perspective on the need for adequate analysis and design for proper foundations for reciprocating and rotating equipment. In completing the article, COMPRESSORTech interviewed three Calgary-based companies involved in foundation design, construction and inspection services. Beta Machinery Analysis (Brian Howes, chief engineer), Primus Engineering (K. Pak, president) and Accurata Inc. (Frank Zabner, compression consultant) were interviewed, with each providing insights and experiences in compressor foundations. Although the companies and individuals perform many more services than mentioned in this article, their comments have been limited to certain areas for brevity.

There are a number of factors that cause gas compression equipment to vibrate, and eventually break down — and poor foundation design is one of them. Recent discussions with industry consultants revealed that many challenges in designing and implementing effective foundations exist. One challenge includes the lack of industry specifications to guide equipment users in the design of foundations where dynamic loads will be used. As a result, many equipment purchasers lack a consistent approach to foundation design, thereby decreasing the reliability of their facilities. In some cases, the lack of proper foundations can create disastrous results.

Why worry about vibration? Vibration is one of the leading causes of high-frequency maintenance and failure of compression equipment. The damage it causes may be obvious and easy to detect, such as the loosening of oil lines and other attached equipment. But it can also be insidious, including fatigue of equipment components and piping that may go unnoticed until failures occur. In both instances, excess vibration leads to higher operating costs, and failures in pressure containment systems can result in gas leaks and serious safety concerns.

Several important elements are included in the analysis and design for reciprocating and rotating equipment foundations. Dynamic foundation analyses are prepared to provide recommendations for pile locations and foundation stiffness. Through the completion of these analyses the likelihood of resonance by the equipment is reduced, which results in reduced vibration within the package.

A variety of dynamic forces from a reciprocating compressor package will affect the analysis and design of the package's foundation. It is the action of the pistons that causes the biggest vibration concern when designing foundations because the pistons create unbalanced forces and couples in the compressor.
In this field project, the foundation was modified. A beam was added under the skid and welded to the existing piles. By adding an extra beam, stiffness was provided midspan to support the equipment above it. If a foundation analysis and design had been completed before construction, a pile would have been installed at that location.
Pre-cast concrete slabs can be constructed with steel plates embedded onto the top of the concrete. These plates are used for welding the skid onto the slab. Plates are also installed for welding the skid under scrubbers, pipe clamps, bottles and building columns. Before the concrete is poured, the plates are positioned to match the corresponding skid members where tie-downs are required. An amount of stick-up must provide sufficient crawl space to accommodate proper welding from below. Some pre-cast concrete slabs come with welding sleeves embedded into the concrete, which allows for the slab’s installation close to the ground and accommodates welding from atop the slab.

The installation of enviropans on compressor packages has caused other challenges, said Howes. The inclusion of these pans requires packages be installed higher to provide welders access to the pilings from below. This additional height increases the likelihood that resonance will occur in the foundation and add to future foundation concerns. “Good foundation designs are important for minimizing vibration,” said Zahner, “but so is sound construction. It is very important to ensure that equipment and foundations are installed correctly.” Zahner cited a number of examples where improper construction resulted in vibration in operating equipment.

In one situation, a skid package had been built on a wide flange for installation at a particular site. When the package was installed, it was not shimmed before being welded to the piles. This resulted in the welds only occurring along the tips of the wide flange, thereby creating a diving board effect and vibration in the package.

In another case, a compressor package had been fabricated with a solid main skid in the center containing all the major equipment components. Along the two lengthwise sides were removable wings that contained a small amount of process piping. The wings had been properly fastened to the center skid, but the foundations under the wings had been reduced. It was believed that because of the wing’s lighter weight, the foundation under the wings could be diminished. The result was a package that resembled a bird in flight, with the movement in the wings causing vibration throughout the package.

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should be clearly outlined in the contracts between the parties involved in the project. When not contractually stated, all consultants agreed that the producer/owner is responsible. Since it is the owner who is responsible for all facets of a project, then, by default, they are responsible for foundation design.

In the absence of dynamic foundation specifications for equipment, users should use the services of companies who specialize in foundation designs. Many facilities are installed using similar foundation designs, regardless of soil and the forces and stiffness associated with the installed equipment. Companies with years of experience and developed expertise in geotechnical engineering should be consulted to reduce the likelihood of equipment vibration.

One common theme for all was that once a producer experiences a vibration problem with a compressor, they quickly realize the need for proper engineering for each project, including the foundation. It is important to get the foundation right, they said, since the last thing an owner wants to do is fix a problem after the package is installed. Producers can either pay upfront to complete a proper foundation analysis, design and implementation, or pay later to fix a vibration problem. The latter is generally more costly. The other alternative is to do nothing and live with the vibration, safety issues, higher maintenance cost and shortened equipment life.

After the piles have been driven to their designed depth, they are cut to the proper elevation and capped. The need for a crawlspace beneath the slab for underside welding can be eliminated when slabs are welded from the top using vertical pipe sleeves. When stick-up is kept to a minimum, the lateral stiffness of the piles is increased.